TRANSMIT DIVERSITY ON A CONTROL CHANNEL WITHOUT ADDITIONAL REFERENCE SIGNALS

TECHNICAL FIELD

[0001] This invention relates generally to radio frequency (RF) reception and transmission and, more specifically, relates to downlink control and shared channels such as for example the enhanced PDCCH (E-PDCCH) and PDSCH in the LTE system.

BACKGROUND

[0002] This section is intended to provide a background or context to the invention that is recited in the claims. The description herein may include concepts that could be pursued, but are not necessarily ones that have been previously conceived, implemented or described. Therefore, unless otherwise indicated herein, what is described in this section is not prior art to the description and claims in this application and is not admitted to be prior art by inclusion in this section.

[0003] LTE is often used to refer to the long term evolution of the Universal Terrestrial Radio Access Network radio access technology, more formally known as E-UTRAN. The LTE system is to provide significantly enhanced services by means of higher data rates and lower latency with reduced cost. In the LTE and other cellular radio systems the base station (termed an eNodeB or eNB in LTE) signals the time-frequency resources allocated to a mobile terminal (more generally a user equipment UE). In LTE the downlink and uplink data resources are allocated via the physical downlink control channel (PDCCH) in terms of physical resource blocks (PRBs). The number of PRBs available in a time slot depends on the bandwidth and varies from 6 to 100, corresponding to bandwidths of 1.25 and 20 MHz respectively.

[0004] In LTE there is frequency selective scheduling for the downlink (DL) and uplink (UL) shared data channels (physical downlink and uplink shared channels referred to as PDSCH and PUSCH) in order to allocate the best PRBs for each terminal. This gives the best performance but is also the most expensive in terms of signaling. While this scheduling technique allows advanced multi-antenna techniques like precoded transmission and multiple input-multiple output (MIMO) operation for the downlink shared data channel, in conventional LTE the downlink control signaling on the PDCCH does not employ any of these gaining mechanisms (e.g., frequency domain scheduling gain, advanced multi-antenna gains). To exploit some of these gaining mechanisms the third generation partnership project (3GPP) organization has initiated a study item for enhanced downlink control signaling using UE-specific reference signals enabling enhanced multi-antenna transmission also for the DL control channel.

[0005] LTE is a heterogeneous network, in which there are access nodes apart from the traditional base stations/eNodeBs which operate at different power levels. For example, there may be privately operated femto nodes to which the conventional (macro) eNodeBs can offload traffic; and/or there may be remote radio heads (RRHs) in traffic hot spot areas or repeaters to fill coverage holes. Heterogeneous networks are susceptible to widely varying interference, and a future release (LTE-Advanced or LTE-A) of LTE is to include a new logical control channel E-PDCCH to better exploit these heterogeneous network aspects as well as the gaining mechanisms noted above.

[0006] It has been proposed that the REs which the E-PDCCH is using within a physical resource block (PRB) pair determine the antenna port (AP) candidates. The UEs have a defined search space in which they must blindly decode in order to find if there is an E-PDCCH directed to them. This search space is limited in order to constrain the complexity and power consumed by the UEs. For example, in conventional PDCCH signaling in the UE specific search space there are six predefined PDCCH candidates for one and two control channel elements (CCEs), and two candidates for four and eight CCEs.

[0007] In conventional LTE the concept of CCEs relates to the PRBs as follows. Depending on the specific frame structure and signaling involved, there are 6 or 7 orthogonal frequency division multiplex (OFDM) symbols per slot. There are two slots per radio subframe and each slot has a duration of 0.5 msec. One RE represents one grid point defined by one OFDM sub-carrier and one OFDM symbol. REs are accumulated into RE groups, and one CCE is defined as a set of RE groups. One PRB represents twelve consecutive OFDM sub-carriers for one slot, and defines the smallest element of resource allocation assigned by the eNodeB scheduler (**1** PRB has a bandwidth of 180 kHz). One PRB pair is the combination of two PRBs in one subframe.

[0008] Also below is discussed the concept of aggregation level, which is also a concept in conventional LTE. The aggregation level gives the size of the UE-specific PDCCH search space candidate. There are also common search spaces in addition. For each PDCCH candidate the UE is to blindly detect to check whether there is a PDCCH addressed to that particular UE. Aggregation level 2 means the corresponding PDCCH candidate in the UE-specific search space spans two CCEs; aggregation level 4 means the corresponding PDCCH candidate in the UE-specific search space spans four CCEs, and so forth.

[0009] Development of the E-PDCCH is still ongoing in the 3GPP. It is agreed that the E-PDCCH will be demodulated by the UE based on demodulation reference signals (DMRS), which is a precoded reference signal. In conventional LTE for the PDSCH, the related DMRS applies the same precoding as what is used for the data resource elements (REs). This enables precoding the transmitted signal such that the signal quality is improved at the UE as follows. For the case in which the eNodeB has channel state information (CSI) information available, which may include precoding matrix information (PMI) feedback, which the eNodeB receives from the UE, the eNodeB may use this CSI to select which precoding vector to use on the E-PDCCH and/or PDSCH it transmits to that same UE, and the UE may demodulate that same E-PDCCH and/or PDSCH it receives using the DMRS corresponding to that precoding vector. But LTE-Advanced may also facilitate the eNodeB transmitting the E-PDCCH to UEs for which it does not have valid PMI feedback, or for which it has detected that the CSI is unreliable, for example. In this case, UE specific precoding may not provide good performance and a transmit diversity transmission scheme might be more suitable. The teachings below enable efficient transmit diversity schemes for a control channel such as the E-PDCCH that is demodulated by the DMRS.